Generation IV Gas-cooled Reactor System Concepts

Technical Working Group 2 -- Gas Cooled Reactor Systems

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Introduction

- Charter- Identify and evaluate advanced gas cooled reactor system concepts for advancing the Generation IV goals
- A DOE RFI and team solicitations resulted in 21 reactor system concepts submitted from France, Germany, Japan, Netherlands, and the U.S.
- The 21 concepts were consolidated into four concept sets
- The four concept sets have been qualitatively screened to assess their potential to achieve the generation IV goals
- The screening used criteria developed by the Evaluation Methodology Group in support of each goal, and measured against existing advanced light water reactor designs

Gas Cooled Thermal Reactor General Features

- Reference concepts used once through LEU fuel cycles
- TRISO fuel -- SiC and pyrolytic graphite fission product barriers
- Graphite moderated, helium coolant
- “Naturally safe” designs with conductive and radiative decay heat removal
- High temperature direct Brayton cycle power conversion
- Increased fuel utilization and decreased HLW due to high thermal efficiency
- Significant fuel cycle flexibility within a reactor design-- LEU once-through, Pu-MA single recycle, W-Pu, HEU, Th-U233 converter

Pebble Bed Reactor Systems (PBR)

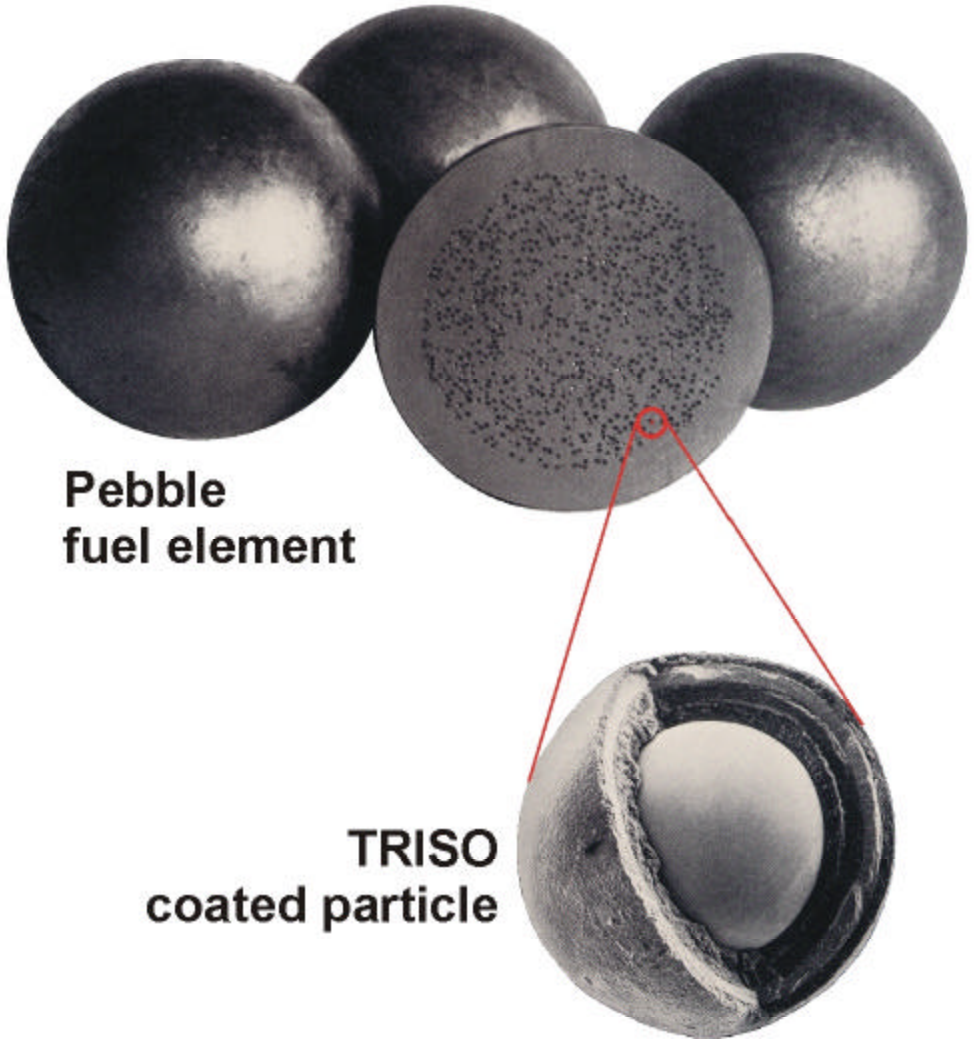
- Five concepts submitted

- Reference concept--
  - 115 MWe, 250 MWth, direct Brayton cycle
  - Low excess reactivity (continuous on-line refueling)

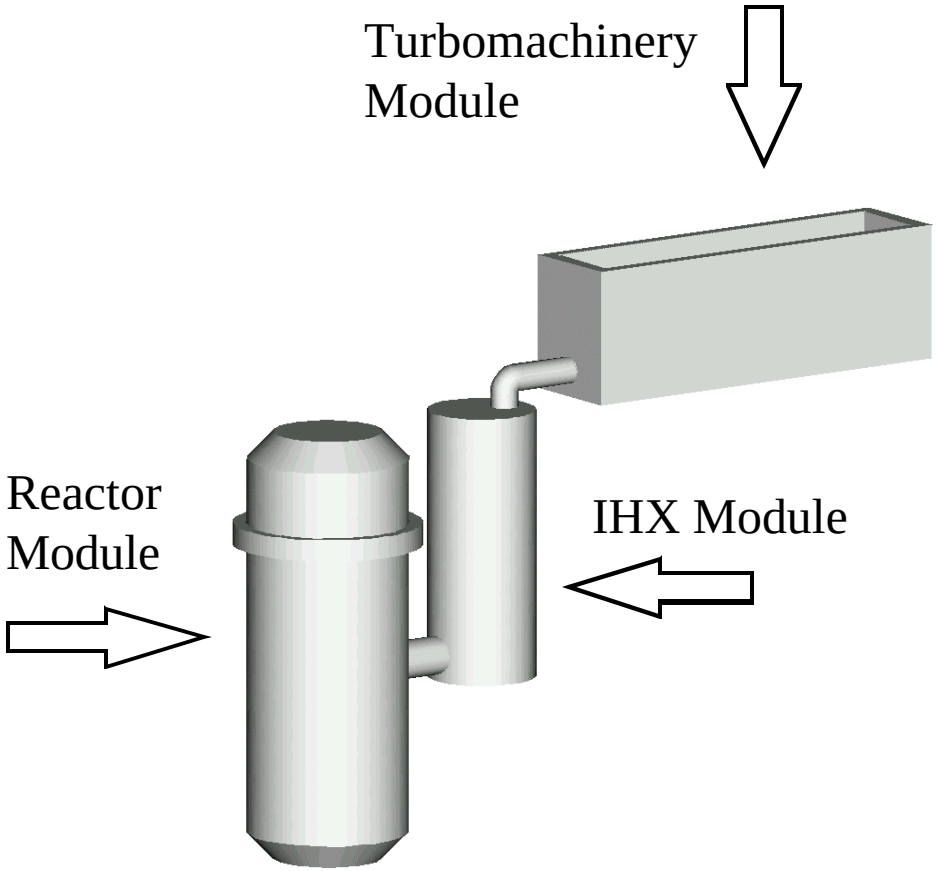
- Shows promise for
  - Modest gains in sustainability
  - Significant advance towards safety goals
  - Comparable economics

PBR Fuel

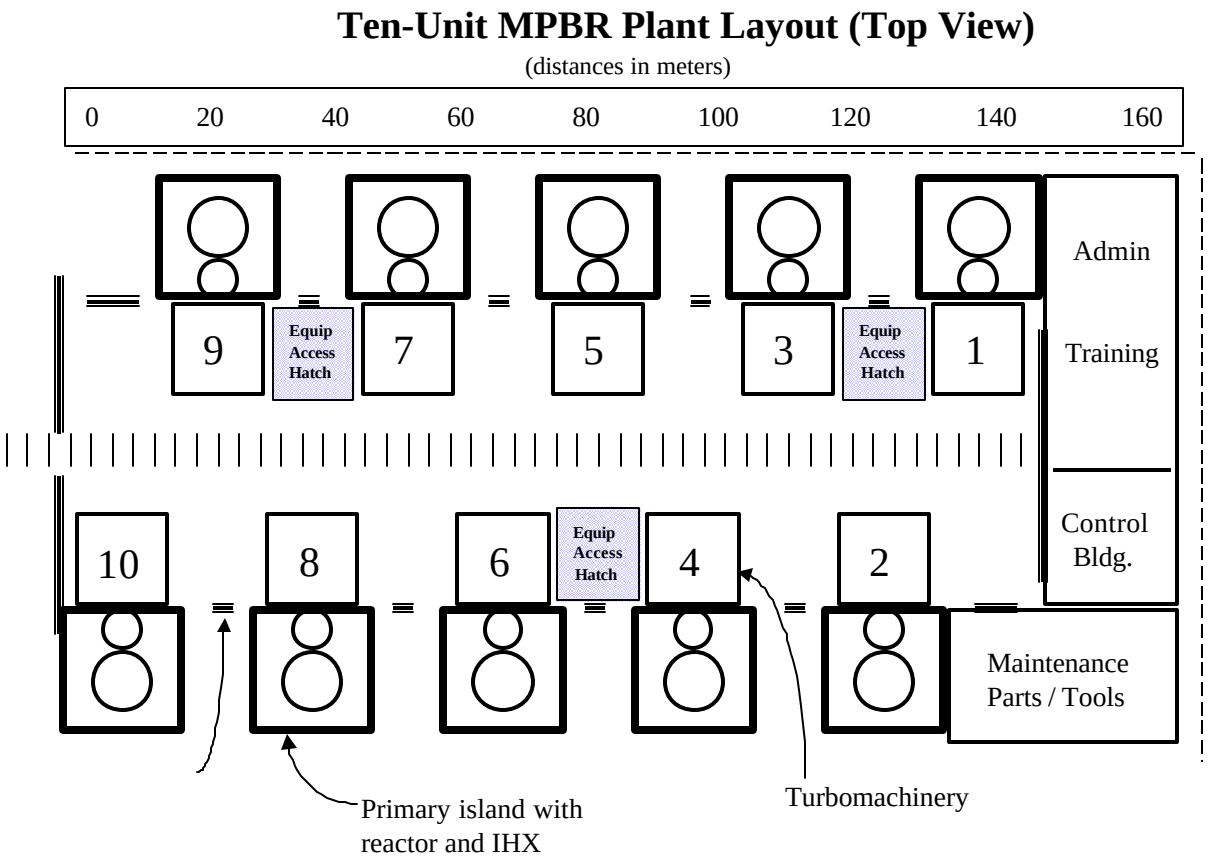
- ***Pebbles are 60 mm***



PBR With IHX



Sample 1150 MWe PBR Plant



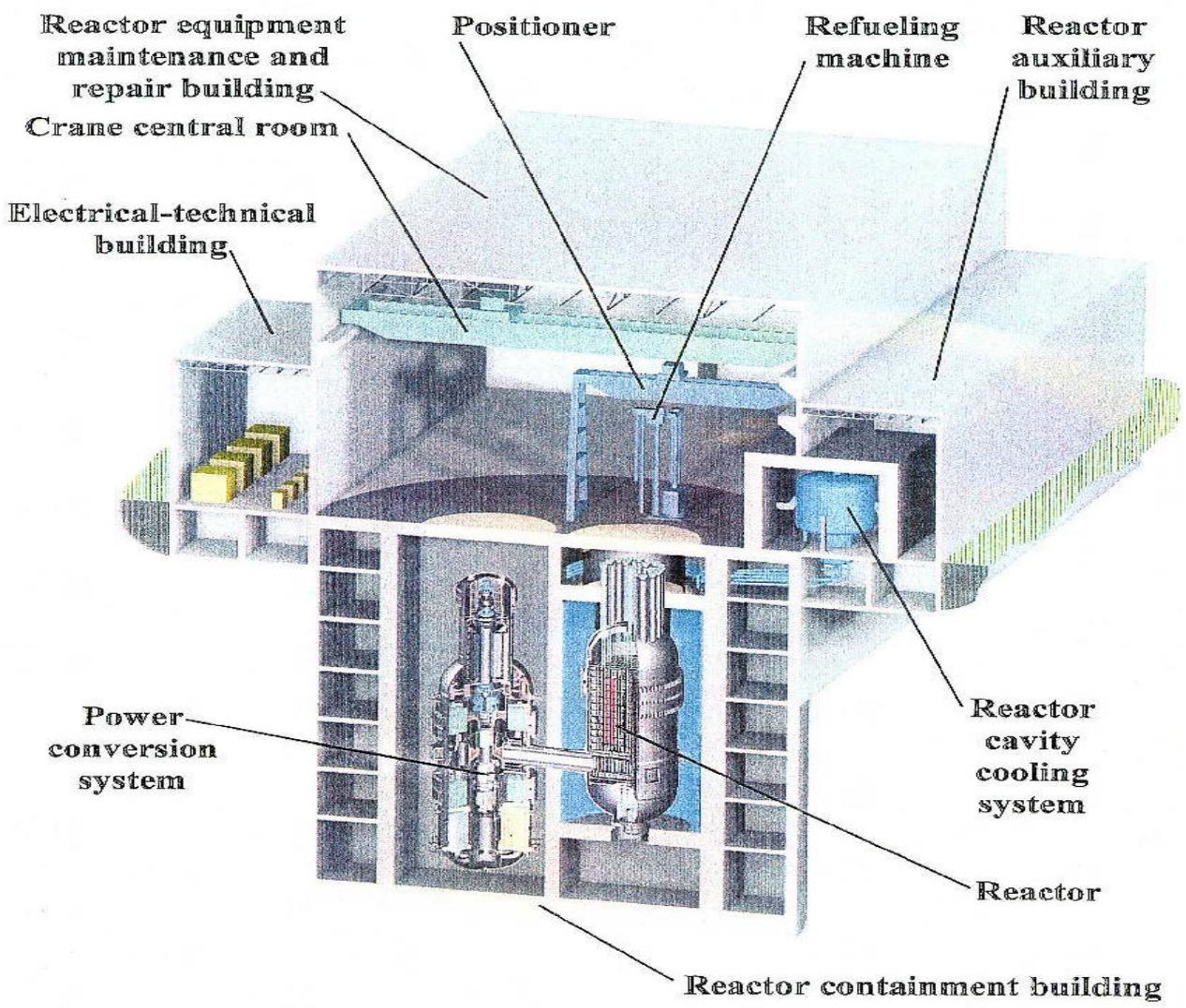
PBR R&D Needs

- Fuel qualification at higher burnups, fluences, and temperatures.
- Beyond design basis event behaviors (air and water ingress)
- Fuel manufacturing quality improvements

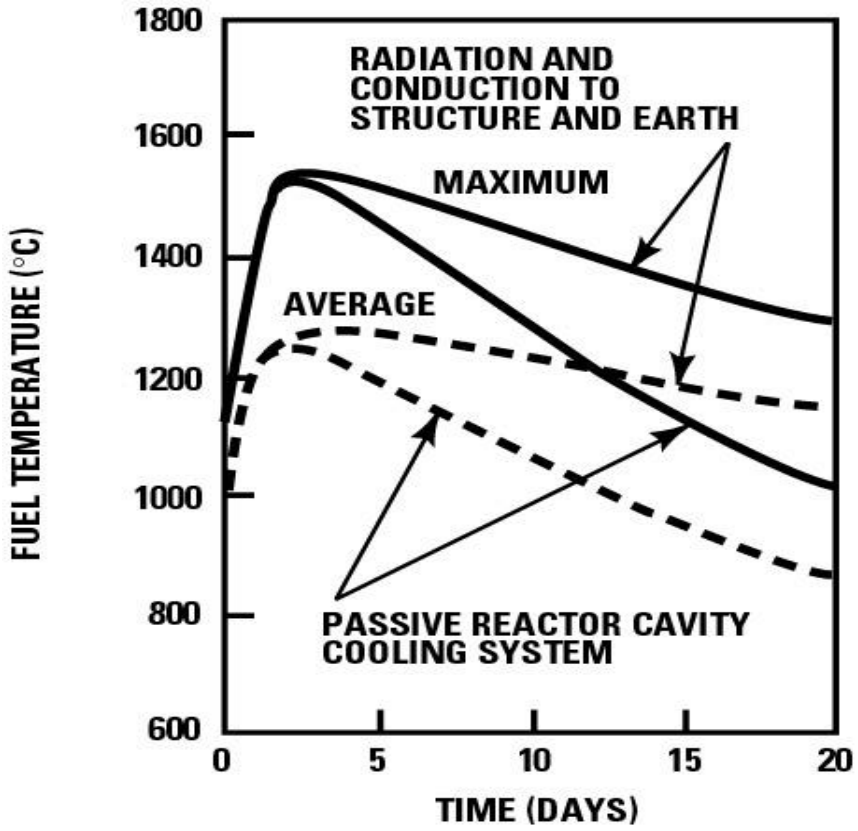
Prismatic Fuel Modular Reactor Systems (PMR)

- Five concepts submitted
- Reference Concept--
  - 286 MWe, 600 MWth, direct Brayton Cycle
  - 850 C core exit temperature
  - LEU once-through fuel cycle
- Fuel cycles submitted included waste transmutation, W-Pu burner, Th-U233 converter.
- Shows promise for
  - Modest gains in sustainability
  - Significant advance towards safety goals
  - Comparable economics

Conceptual PMR



PMR Response to Loss of Coolant



PMR R&D Needs

- Similar to PBR
- Fuel performance qualification
- Fuel manufacturing quality
- Higher temperature vessel materials qualification
- Turbomachinery bearings

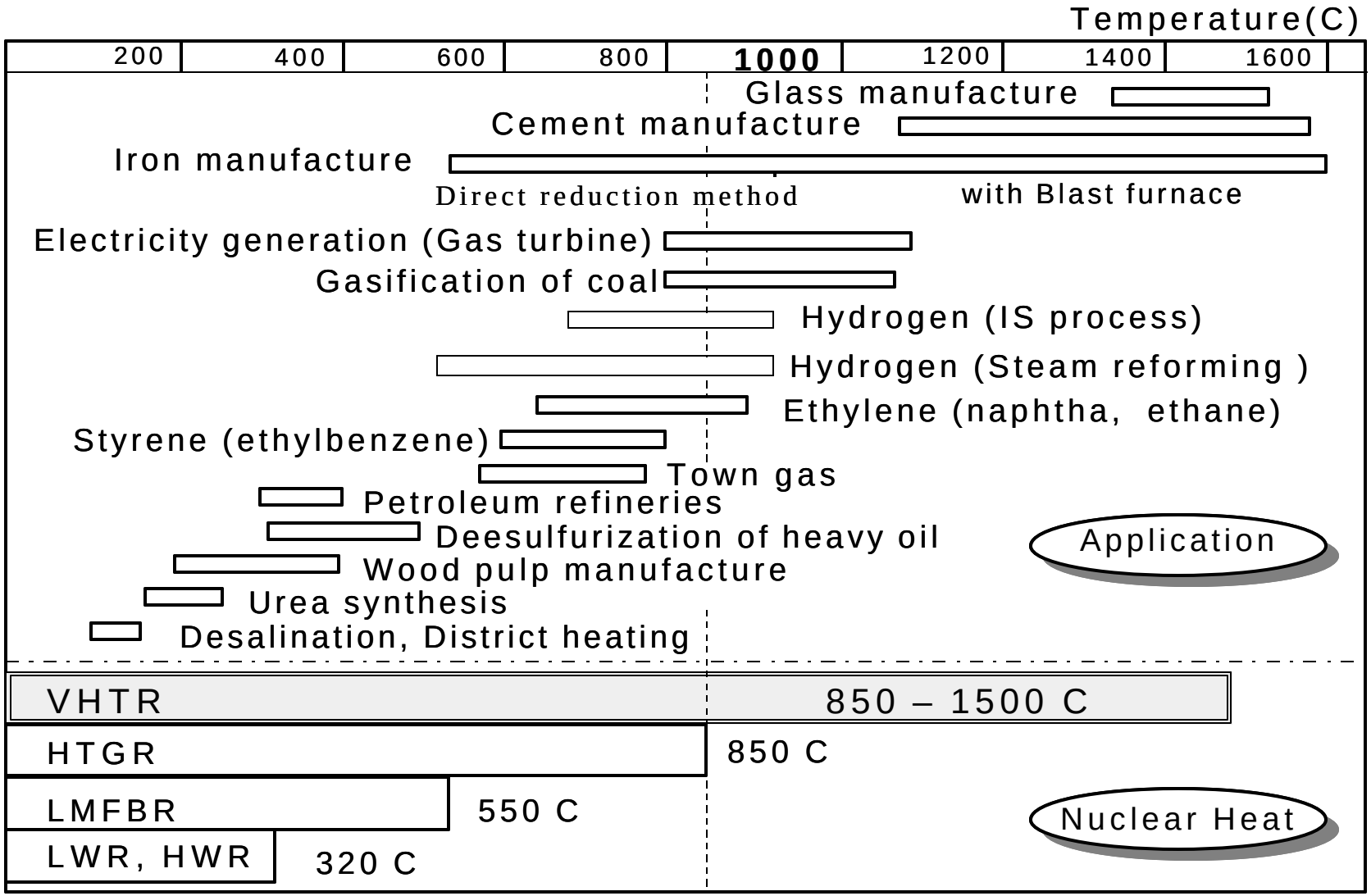
Very High Temperature Reactor Systems (VHTR)

- Four concepts submitted
- General features of VHTR--
  - >900 C coolant core exit temperature
  - prismatic core, 600 MWth, LEU once-through cycle
- Shows promise for
  - Gains in sustainability and flexibility
  - Significant advance towards safety goals
  - Comparable economics

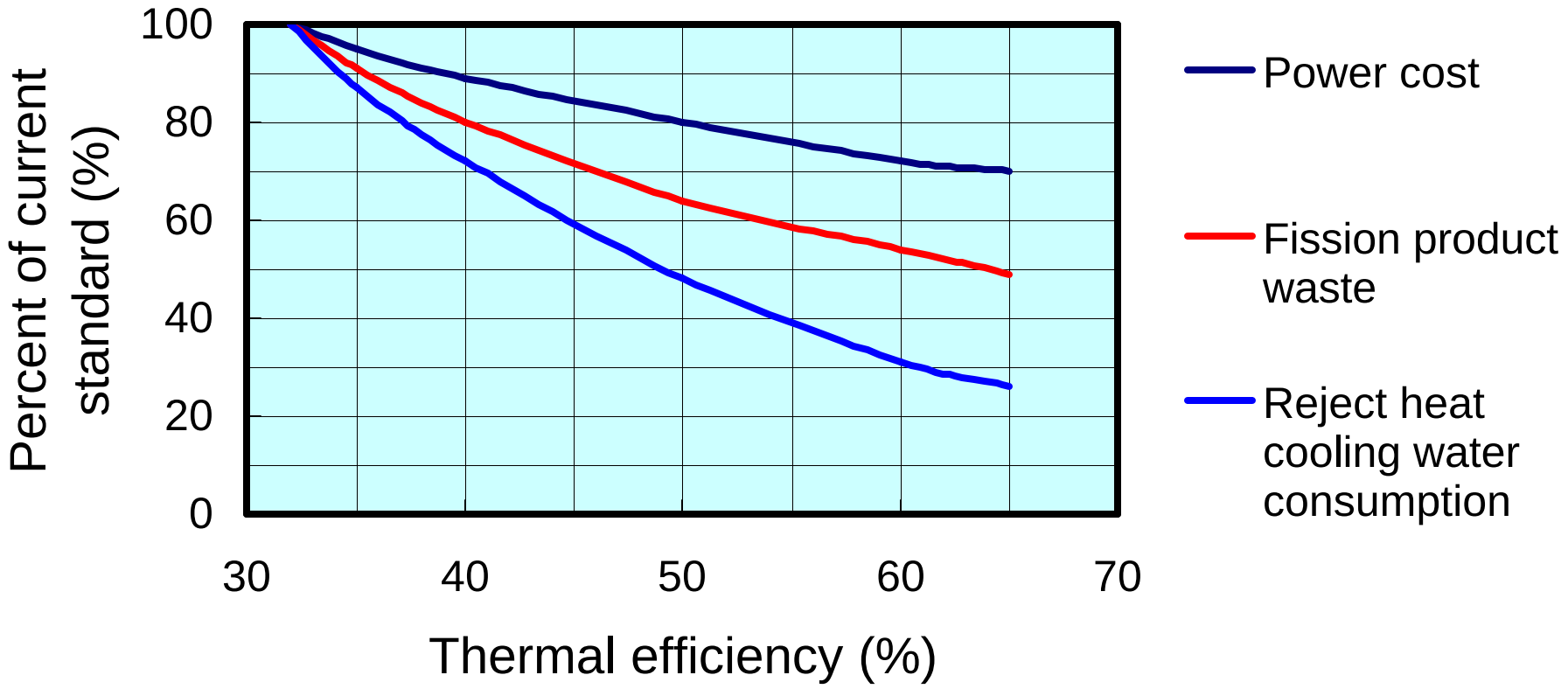
Motivation for VHTRs

- 30 % of world primary fuel use is to generate electricity
- 17 % of electricity uses nuclear fuel
- Nuclear power can offset other primary fuels in applications other than electricity
- VHTRs may significantly reduce liquid and gaseous fossil fuel demands

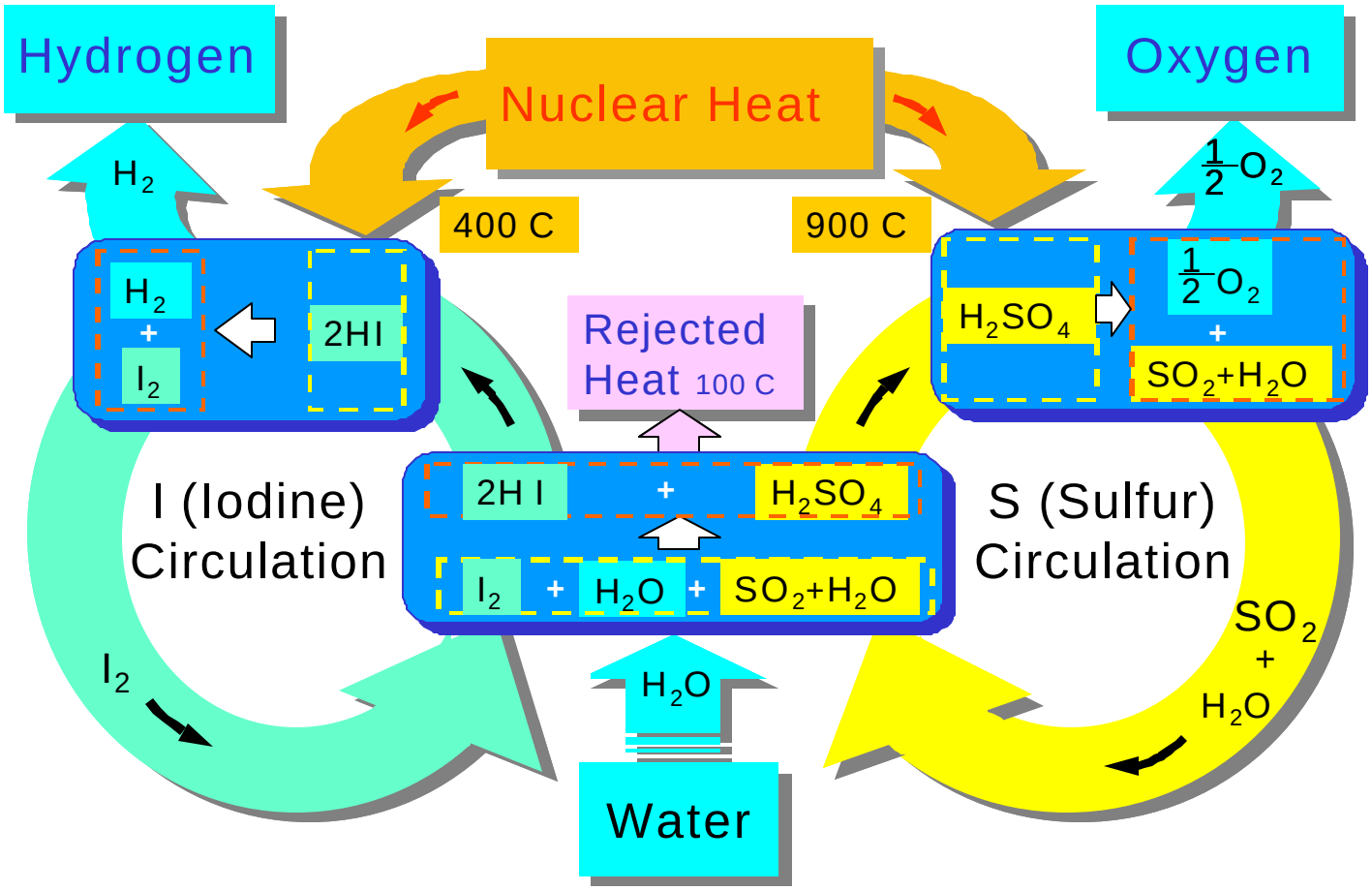
Process Heat Applications



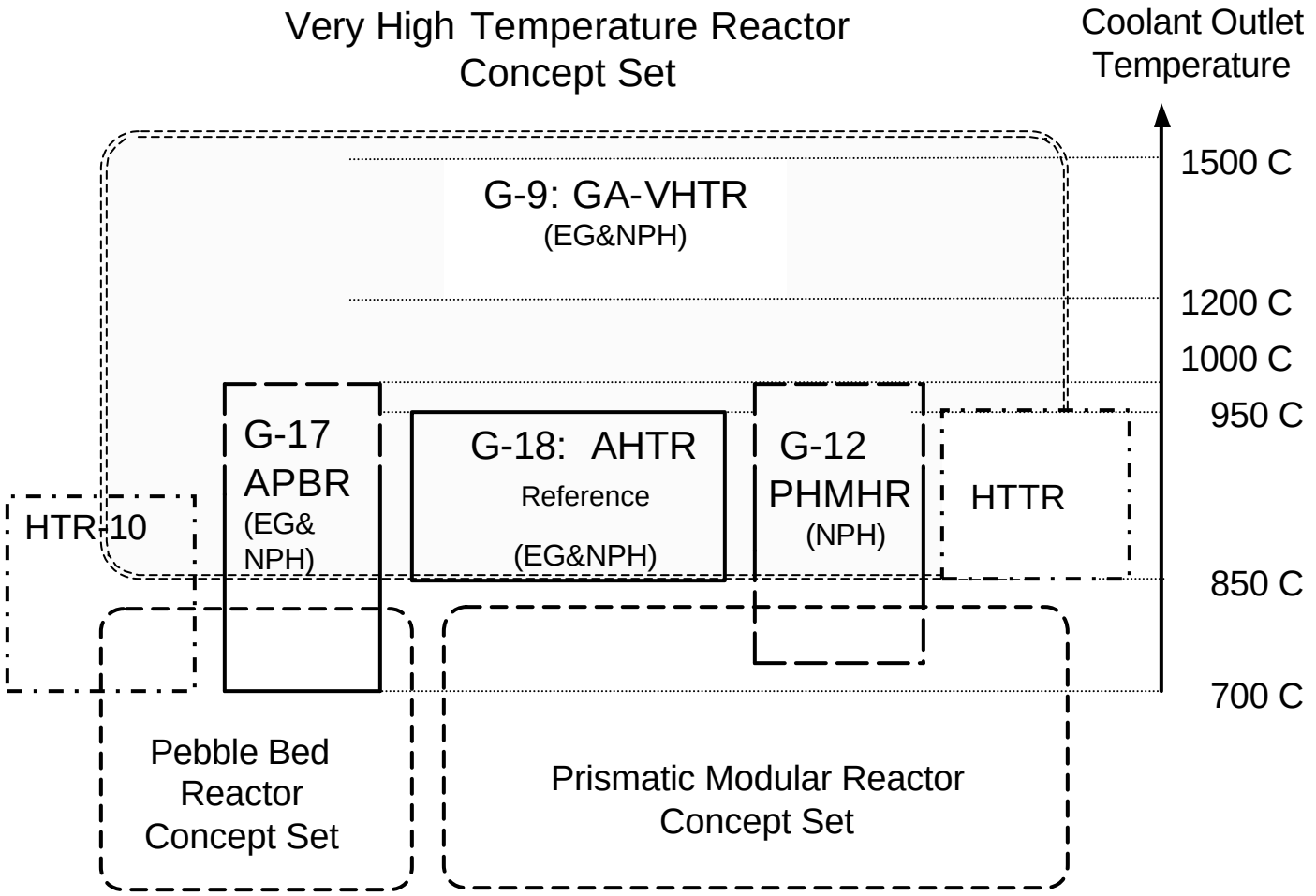
Effect of temperature on Sustainability



IS Process for Hydrogen Production

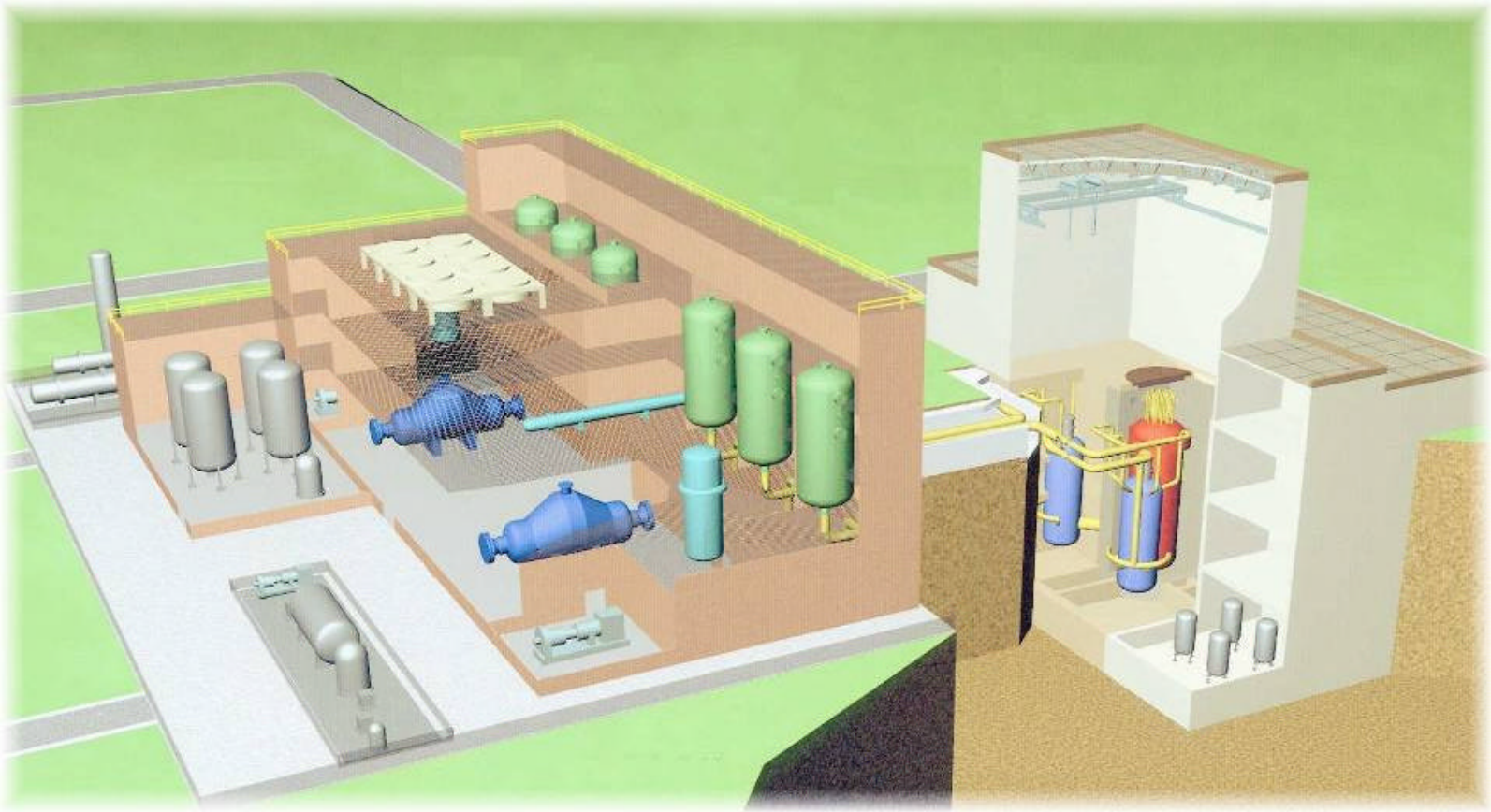


Temperature Capability of Concepts



EG-Electrical Generation NPH-Nuclear Process Heat Applications

Reference VHTR with IHX and Hydrogen Production



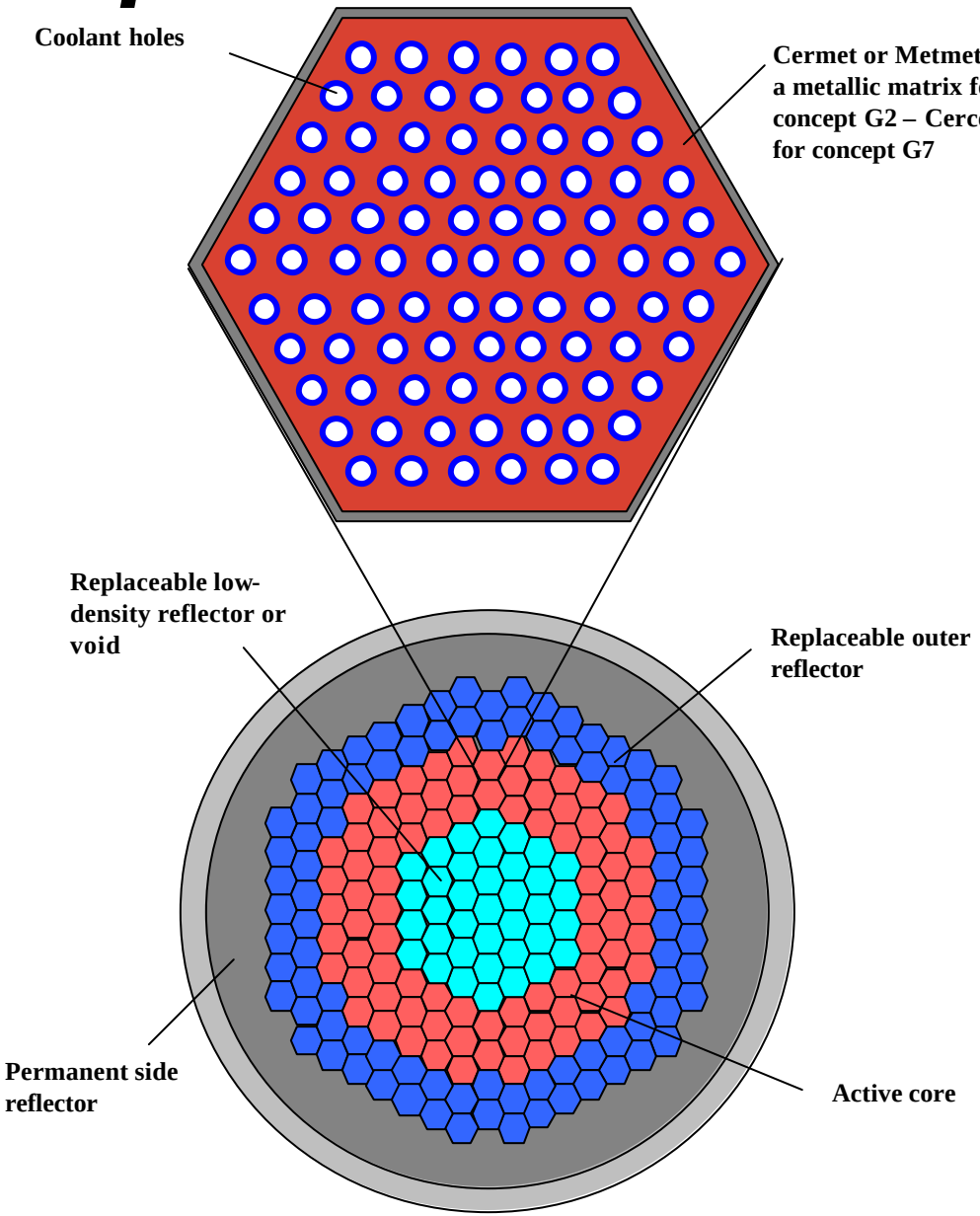
VHTR R&D Needs

- Higher temperature fuels (e.g. ZrC instead of SiC)
- Higher temperature materials (e.g. ceramic structures)
- Passive decay heat removal systems (e.g. heat pipes)
- High Temperature IHX

Gas Cooled Fast Reactor Systems (GFR)

- Four concepts submitted
- No complete reference concept
- Novel features of the four concepts may illuminate future development pathways.
- Three concepts use helium coolant, one uses CO2.
- Rely upon recycle.
- May allow passive decay heat removal
- Show promise for
  - Significant advance in sustainability
  - Comparable safety performance
  - Unclear economics

Example GFR Prismatic Fuel



GFR R&D Needs

- Fuel, structural and core materials
- Passive safety system capabilities
- Recycle techniques

Summary

- The advanced gas-cooled thermal reactor system concepts show promise for--
  - Modest improvements in sustainability
  - Significant improvement toward safety goals
  - Comparable economics with the potential for major improvement in applications other than electricity
- Fast reactor concepts show--
  - Significant improvement toward sustainability goals
  - Much development is needed to define promising concepts
- All concept sets allow high temperature process heat applications, in addition to electrical generation. The VHTR concepts allow more applications and higher efficiencies.
- The next step is to quantitatively assess the concept sets and define R&D scope.